Amplitude and Phase Characterisation of Femtosecond Pulses in a Photodiode-Based Autocorrelator

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Published in:
Conference on Lasers and Electro-Optics Europe, 1998. 1998 CLEO/Europe

10.00 CMA7

Amplitude and Phase Characterisation of Femtosecond Pulses in a Photodiode-Based Autocorrelator

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Second-order autocorrelation of ultrashort laser pulses by using two-photon-induced photocurrent in semiconductors offers several advantages compared with traditionally employed combination of a second harmonic (SH) crystal and a photomultiplier tube. A low-priced commercially available photodiode [1] allows to overcome principal drawbacks of SH-based autocorrelation: limited phase-matching bandwidth and wavelength-dependent sensitivity of the light detector leading to a spectral *filtering effect, pulse broadening due to crystal* bulk dispersion, low conversion efficiency which decreases with increase of SH bandwidth, high cost and manufacturing problems associated with thin SH crystals. A significant advantage of incorporating a semiconductor photodiode into autocorrelation measurements is that the desired two-photon response and the transformation of light into electric current are combined into a single solid-state device. It has been shown recently that for the vast majority of practically realisable pulses the complete phase and amplitude information could be rapidly recovered from the autocorrelation trace and the pulse spectrum by means of a two-stage iterative algorithm [2]. In this contribution we demonstrate that due to absence of spectral filtering effect and high dynamic range of quadratic response to the incident intensity in a GaAsP photodiode [1], correct retrieval of temporal profile and phase from autocorrelation and spectrum can be achieved for ultrashort laser pulses with bandwidths as large as 130 nm and pulse energies as low as several pJ.

Figure 1 presents the autocorrelation function of pulses from a KLM Ti:sapphire laser measured in the photodiode (Fig.1a, solid line) and pulse spectrum (Fig.1c, shaded contour). The pulse profile from the autocorrelation was restored by using an iterative Temporal Information via Intensity (TIVI) algorithm [2], as depicted in Fig.1b (circles). The autocorrelation fit is shown in Fig.1a (dashed line). The missing phase information has been subsequently extracted via iterative Gerchberg-Saxton algorithm [2] from the pulse spectrum. *The resulting from this algorithm temporal and spectral phase* are shown respectively in Fig.1b and Fig.1c by dashed lines. Typically, convergence of each part of the algorithm was achieved after 20-30 iterations. Since both algorithms consist of Fourier transformations of one-dimensional arrays, they have extremely high computational efficiency and are easy to implement with a real-time autocorrelation measurement.

To prove the validity of our approach we performed FROG measurements of the same pulses. The results of FROG inversion shown in Fig.1b and Fig.1c as solid lines, fully corroborate with the data obtained with the photodiode.

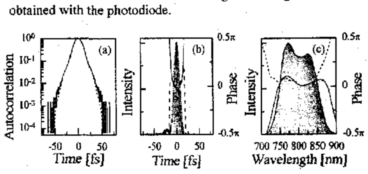

Fig. 1. (a) Measured (solid) and fitted by the TIVI algorithm (dashed) autocorrelation traces. (b) Pulse intensity profiles extracted by TIVI (circles) and FROG (shaded contour), and temporal phases derived by Gerchberg-Saxton method (dashed) and FROG (solid). (c) Measured spectrum (shaded contour), and spectral phases obtained by Gerchberg-Saxton method (dashed) and FROG (solid).

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10.15 CMA8

Wave-Front Correction of Femtosecond TeraWatt Laser using a Deformable Mirrors

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Chirped Pulse Amplification (CPA) allowed the development of ultrashort, high intensity lasers. For many applications, laser users are interested in reaching the highest intensity focused on target. Often neglected, the spatial quality of the beam is crucial in this regard[1]. Wave-front distortions can significantly affect this spatial quality and thus severely reducing the attainable focused intensity. In fact, the wave-front of multi-Terawatt lasers, because of thermal effects and the size of optical elements, features sizeable distortions. The correction of the wave-front and a better confinement of *the energy is thus a solution much less expensive* than adding one more amplifier stage to the laser chain to actually obtain the same peak intensity. To quantify this decrease in the peak focused intensity, we use the normalized Strehl intensity which is the ratio of the peak intensity at focus of a beam with a distorted wave-front to that of the same beam without distortions. We present, in this paper, the wave-front correction of a femtosecond TeraWatt CPA lasers using an Achromatic Three-Wave Lateral Shearing Interferometer (ATWLSI)[(2)] and a deformable mirror.

This experiment is performed at 1053 nm on a Table Top Terawatt system (T^3).This laser is a glass amplifier laser which delivers 450-fs pulses. To improve to focusability of the complete system, we first corrected the wave front, at the end of the laser chain at low energy. In this case, we wanted to compensate the distortions independent of the energy such as those occurring in the optical and CPA elements. For the correction, we use a 37 electrostrictive-actuators mirror with a diameter of 5 cm. We improved the wave-front by decreasing the distortions from 0.7 λ to 0.3 λ (peak-to-peak value). The Strehl ratio was thus increased from 35% to 88%, or by a factor 2.5 (Fig. 1). The plot of the figure 1 shows us the three focus spots: without correction, with correction and with flat wave-front (diffraction limited) according to the measurement of the intensity and the phase in the near-field. The different full-width-half-maximum (FWHM) for each beam have also been calculated to show that a significant loss in the peak intensity at focus does not necessary lead to a large broadening of the spot. In fact, the non-corrected wave-front have only a broadening of 1.29 for a loss of the maximum focused intensity by a factor 3. Subsequently we also correct the wave-front of the laser at high energy (700 mJ) in order to take into account the thermal distortions. We improved the wave-front from 1.5 λ to 0.45 λ and so the Strehl ratio from 22% to 83%. The gain of the peak intensity is then 3.8.

The single-shot wave-front characterization of femtosecond laser pulses using the ATWLSI and subsequent correction with an adaptive mirror has shown a significant improvement of the focusability of a 450-fs 1053-nm Terawatt type system.

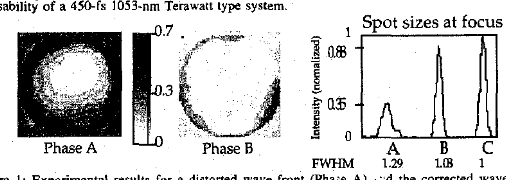

Figure 1: Experimental results for a distorted wave-front (Phase A) and the corrected wave-front (Phase B) for the TeraWatt laser at low energy with peak-to-peak values of respectively 0.7 λ and 0.3 λ. The graph represents a line-out of the focus spots calculated with the intensities and phase measurements: A: is with the Phase A, B: is with the Phase B and C: A: is with a flat phase.

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